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in human blood.<sup>6</sup> It seems therefore conceivable that the high content of the non-protein nitrogen in the fish blood, accompanied by a slow circulation, might favor the deposition of waste products, and at the same time their slow removal would further tend to increase the accumulation.

<sup>1</sup> Donaldson, H. H., *J. Comp. Neur., Wistar Inst., Philadelphia*, 19, 1909, (155-167).

<sup>2</sup> Kellicott, W. E., *Amer. J. Anat., Wistar Inst., Philadelphia*, 8, 1908, (319-353).

<sup>3</sup> Donaldson, H. H., On the percentage of water in the brain of the summer flounder (*Paralichthys dentatus*) according to the body weight. MS. 1905.

<sup>4</sup> Scott, G. G., *Proc. Soc. Exp. Biol. Med., New York*, 9, 1912.

<sup>5</sup> Donaldson, H. H., *J. Comp. Neur., Wistar Inst., Philadelphia*, 26, 1916, (443-451).

<sup>6</sup> Hatai, S., *Ibid.*, 28, 1917, (361-378).

## THE ROTATION AND RADIAL VELOCITY OF THE CENTRAL PART OF THE ANDROMEDA NEBULA

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Indications of rotation in spiral nebulae are quickly obtained by means of spectrographs of very short focus and small dispersion, especially when a wide slit and devices for narrowing the spectrum are used. For definitive values of the rotation, however, it is necessary that the scale be relatively large, the slit narrow, and the exposures very long.

To investigate the rotation of the great nebula in Andromeda, which had been reported by V. M. Slipher at the nineteenth meeting of the American Astronomical Society, an exposure of seventy-nine hours was made during August, September, and October, 1917, with the focal-plane spectrograph of the 60-inch reflector. This instrument which is used at the primary focus of the large mirror has a collimator of 135 mm. focus, a 60° prism of ultra-violet glass, and for the camera a 154 mm. Cooke lens. The dispersion is such that 5.3 mm. corresponds to the interval from  $\lambda$  4930 to  $\lambda$  4950. The ratio of focal lengths of camera and collimator is 1.14, and the spectrograph therefore magnifies the image on the slit by this amount.

TABLE 1

DISTANCE FROM NUCLEUS		NUMBER OF SECTIONS	ADAMS	MISS BURWELL	MEAN
<i>seconds</i>			<i>km.</i>	<i>km.</i>	<i>km.</i>
South Prec.	{ 162.....	1	(-355)	(-469)	(-412)
	{ 121.....	2	369	400	385
	{ 66.....	2	342	342	342
	{ 25.....	1	310	312	311
	{ 0.....	1	307	317	312
North Foll.	{ 41.....	2	288	308	298
	{ 96.....	2	278	288	283
	{ 137.....	1	(292)	(257)	(274)

During the exposure the slit crossed the nucleus and coincided with the major axis which lies in position angle  $40^\circ$ . The slit-width was 0.025 mm., and the spectrogram was traversed longitudinally by comparison spectra at intervals of 1 mm. (see fig. 1).

The results of measures by Mr. Adams and Miss Burwell are given in table 1. The correction for the earth's motion is slight and has been neglected. To reduce the accidental errors and equalize the weights somewhat, results for adjacent sections of spectra in the outer regions have been combined. The values for extreme sections, which are very uncertain, are given separately and appear in parentheses in the table. The values of the distance from the nucleus have been corrected for magnification by the spectrograph. The tabulated radial velocities must be corrected for the inclination of the nebula to the line of sight. Assuming the nebula to be circular, the ratio of the major and minor axes of its apparent elliptical outline, which is 4 to 1, is a measure of the inclination. We thus find approximately  $14^\circ$  as the inclination, and the velocities must accordingly be multiplied by 1.03 to reduce them to the plane of the nebula.

The mean velocities of table 1 are shown in figure 2, the ordinates being kilometers per second and the abscissae seconds of arc. The velocity curve

$$y = -0.48x - 316$$

was determined graphically. From this equation we find:

1. The radial velocity of the nebula is  $-316$  km., a value in good agreement with the earlier measures:

	km.
Pease and Adams <sup>1</sup> .....	-329
Pease and Adams <sup>2</sup> .....	-297
Slipher <sup>3</sup> .....	-300
Wolf <sup>3</sup> .....	-350
Wright <sup>3</sup> .....	-304

2. The linear velocity of rotation at a point 2 minutes of arc from the nucleus is 58 per second.

3. Within the distance measured and the limits of accuracy of the measures the change of rotational velocity with distance seems to be linear, although there may be variations at individual points in the nebula.

4. Whether the motion of the nebula is inward or outward along the arms of the spiral depends upon the inclination of the nebula.

From a spectrogram of eighty-four hours exposure made at intervals during August, September, and October, 1916, with the slit placed on the minor axis of the nebula, Mr. Adams obtains the results shown in table 2.

These velocities, which are nearly constant, are also shown in figure 2 the velocity curve obtained for points along the major axis, and greatly with

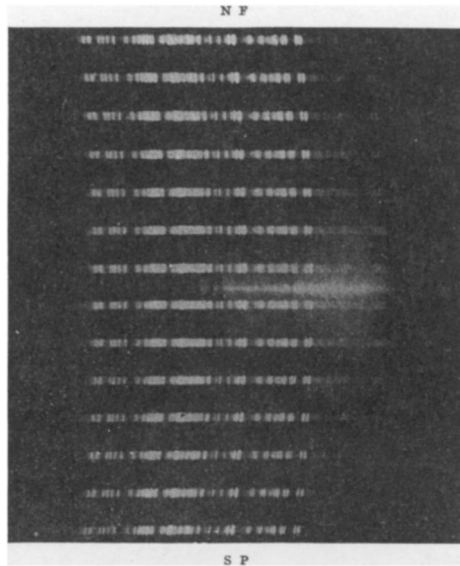


FIG. 1. SPECTRUM OF THE CENTRAL PARTS OF THE ANDROMEDA NEBULA. EXPOSURE 79 HOURS

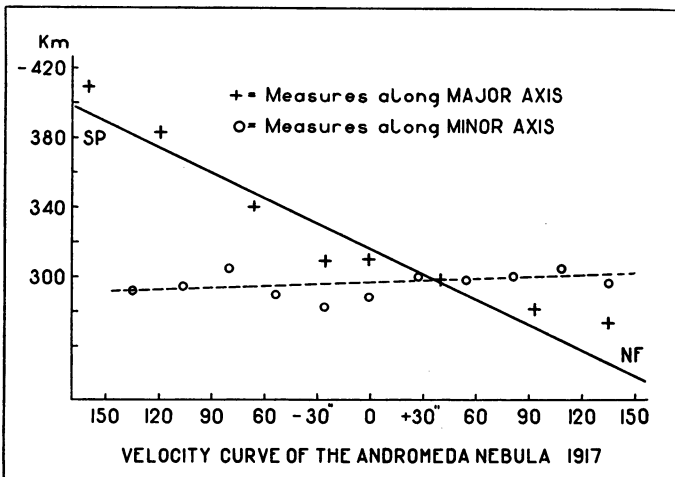


FIG 2

strengthen the conclusions derived from the latter by showing that the variable velocity given by the spectrogram first described is without doubt to be attributed to the rotation of the nebula.

The arms of the cross in figure 3 indicate the length and position of the slit on the nebula.



FIG. 3. DIAGRAM SHOWING THE LENGTH AND POSITIONS OF SLIT ON THE NEBULA

TABLE 2

SECTION OF SPECTRUM	RADIAL VELOCITY	NUMBER OF LINES
	<i>km.</i>	
5th, below.....	-293	3
4th.....	297	4
3rd.....	306	7
2nd.....	291	5
1st.....	284	6
Nucleus.....	291	9
1st, above.....	300	8
2nd.....	299	6
3rd.....	302	6
4th.....	306	4
5th.....	-297	5
Mean.....	-297	

Both spectrograms show a solar-type spectrum entirely free from bright lines. Mr. W. P. Hoge assisted in the guiding during the long exposures.

<sup>1</sup> Pease, F. G., *Pub. Astr. Soc. Pac., San Francisco, Cal.*, 27, 1915, (134).

<sup>2</sup> This paper following.

<sup>3</sup> Slipher, V. M., *Pop. Astr., Northfield, Minn.*, 23, 1915, (21-24), page 23.